Evaluating Performance of Fault Current Limiters in Electric Substations Using Monte Carlo Method

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Abstract

Application of Fault Current Limiters (FCL's) seems a promising alternative to upgrade system breakers and switchgears in areas with heavy demand growth. These devices are mainly expected to improve reliability by reducing fault current values to levels interruptible by existing switchgears, and therefore ensuring safer and more reliable operation of power apparatus. Power substations are one of the ideal candidates for application of FCL's.
In this work, Monte Carlo simulation method has been used to study performance of fault current limiters and their impacts on different components. Results show effectiveness of these device in reducing the average fault current passed through power system components and reducing the associated burdens.

Introduction

What is a Fault current Limiter?

Fault current contain high energy which is not only harmful to equipment and personnel but also create major disturbances that could lead to catastrophic events. In past decade there has been tremendous growth in generation to meet the requirement of customers and as a result power grid is now more in risk of higher fault currents compared to the past. Although most components come with extensive withstand capacity against the short circuit currents, but in most cases, compared to the total generation and potential fault capacities, these limits are small and are getting more and more vulnerable to get crossed. If the fault level surpasses the exiting switchgear rating, it becomes necessary to find cheaper alternatives to replacing the switchgears which in most cases is a costly solution. This is where we use fault current limiters (FCL's). FCL reduces the fault current and provides the opportunity to use lower rated rated protective devices in more cost efficient way. It also reduces the short circuit level that would lead to more secure system operation.

There is many different types of FCL devices. Even though there is not a general specification for a fault current limiter, the most common types of FCL's can be classified as fault current limiting reactors, high voltage current limiting fuses, pyrotechnic fault current limiters (Is-limiter),thyristor controlled series compensator with fault current limitation, solid state limiter and superconductive fault current limiters.

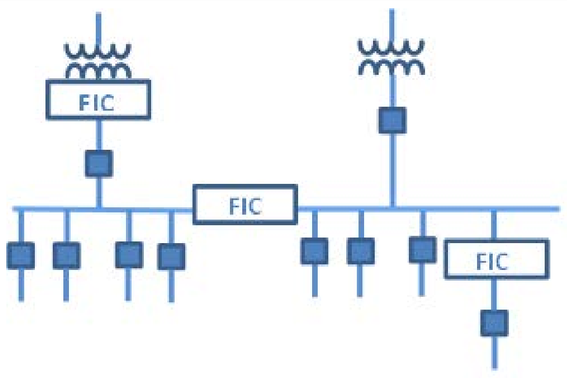
Why we need fault current Limiter?

The FCL provides:

1. Rapid Response to fault current
2. Low Impedance in normal operation
3. High impedance during fault

Analysing the system employing with FCL and system without FLC shows that system with FCL is highly reliable. Some of the failure mode of the substation which cause interruption of the load points in the absence of the FCL are eliminated when FCL is employed.

Potential Locations of FCL in the Power System



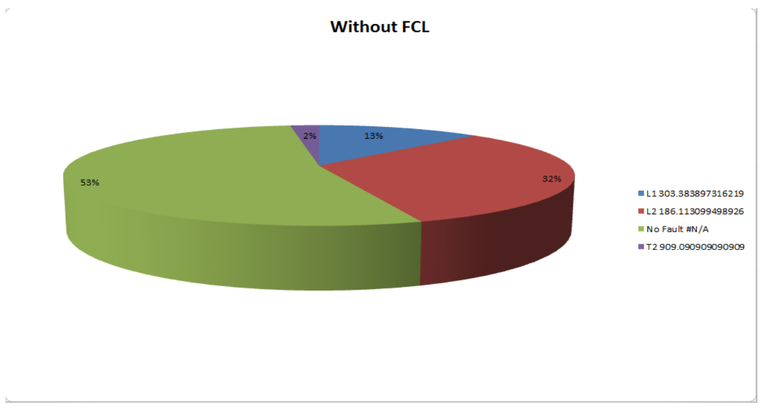
FCL can be applied in multiple distribution or transmission areas. Among the various possible locations for FCL's, bus –tie location represents an effective solution to the fault current problem since it has the following advantages.

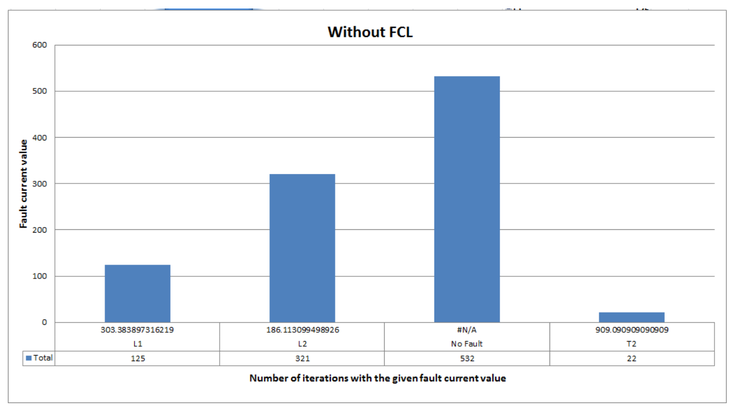
1. Separate buses can be tied together without a large increase in the fault duty on either bus
2.During a fault, a large voltage drop across the limiter maintains voltage level on the un-faulted bus.
3. The paralleled transformers result in low system impedance and good voltage regulation; tap-changing transformers can be avoided
4. Excess capacity of each bus is available to both buses, thus making better use of the transformer rating

Monte Carlo Simulation:

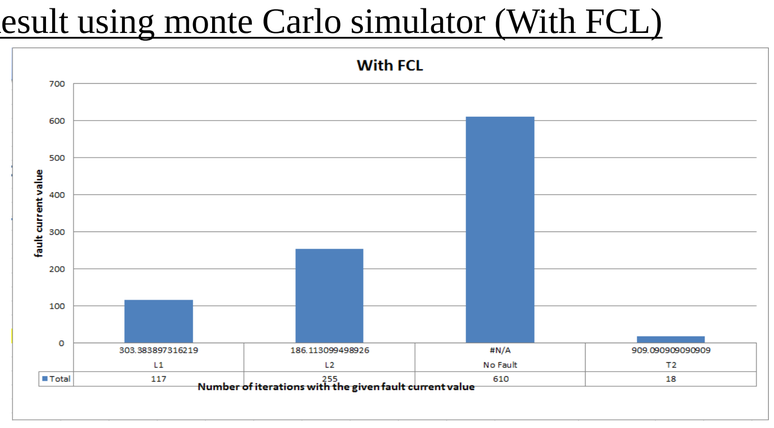
Monte Carlo simulations are used to model the probability of different outcomes in a process that cannot be easily predicted due to the intervention of random variables. It gives way to foresight the outcome, by changing the variable of uncertain part of the mathematical model and run for several time to get the result.
In this project, Monte Carlo simulation has been used to find impact of fault current limiter on probability distribution of fault current. At each step, random numbers representing probability of failure of various component are generated. If a generated random number is greater than a specific threshold, the associated component is being considered as faulty. Fault calculation is then carried out for that component and resultant current value are stored. At the end of iterations, stored values for fault currents are compared and their average value and standard deviation are calculated.

Result using monte Carlo simulator (Without using FCL)





Result using monte Carlo simulator (With FCL)



Conclusion

In this phase of the work, Monte Carlo simulation was used to find distribution of fault current levels with and without FCL. In the next phase of the project, the developed model will be used to calculate failure rate of the components at each iteration, and obtain average failure rate of componnets with/without FCL. Results will assist in reliability worth/reliability cost analysis of FCL devices in electric substations, in terms of failure rate reduction caused by FCLs and their installation costs.